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B71 01027

SUBJECT: Mariner Mars '71 Mission B - A Proposed Change in Orbital Period - Case 235

DATE: January 26, 1971

FROM: G. A. Briggs

## ABSTRACT


The 32.88 hour period of the nominal MM '71 Mission B orbit (the so-called 4/3 orbit) permits repeated overflights of three regions of Mars every four Mars days. It is proposed that the period be changed to 20.55 hours such that six regions would be overflown every five Mars days - a 5/6 orbit. The principal advantage that such a change would provide is a 100% increase in longitudinal coverage and an approximate 50% increase in the total data returned. The principal disadvantage is a reduction in planet-in-view time on each revolution early in the mission.

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## MEMORANDUM FOR FILE

### Introduction

The nominal orbital configurations for the two Mariner Mars '71 spacecraft are:

| | Mission A | Mission B |
|---|---|---|
| Period (hours) | 11.98 | 32.88 |
| Inclination (degrees) | 80 | 50 |
| Periapsis Altitude (km) | 1250 | 850 |
| Initial Periapsis Latitude (degrees) | 32S | 4S |
| Ellipse Orientation Angle* (degrees) | 130 | 155 |
| Insertion Date | 11-14-71 | 11-24-71 |

Mission A is primarily intended to acquire extensive contiguous mapping coverage of Mars. A swath of mapping photographs will be obtained on each revolution near the evening terminator using a camera having an 11° x 14° field of view. The altitude of periapsis is the lowest consistent with providing contiguity between successive vertical photographs (taken at 84 second intervals) near periapsis.

Mission B, by contrast, is designed principally to investigate time variable phenomena on Mars, both seasonal and diurnal. To this end an orbital period 'harmonically' synchronized with the Mars rotation period has been adopted to permit repeated

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*The ellipse orientation angle is the angle between the approach asymptote and the line of apsides.

viewing of chosen regions on the planet. The lower inclination of the B mission orbit has been selected to permit improved viewing of terrain at southern mid-latitudes where seasonal changes are expected to be most pronounced. The periapsis altitude, which is 50% lower than that of mission A, is constrained from being still lower by planetary quarantine requirements.

The purpose of this memorandum is to discuss an alternative harmonic for the mission B orbital period: 5/6 (20.5 hours) instead of the nominal 4/3 (32.8 hours). Before coming to this matter it is necessary to review briefly the principal features of the nominal mission B design.

## Review of Mission B Orbit Characteristics

A general representation of the geometry of the mission B orbit is shown in figure 1. The figure also shows when the center of the planet can be photographed from the spacecraft. A limitation on the field of view arises because the spacecraft maintains a fixed orientation to the sun, and the spacecraft hardware restricts the camera view, roughly speaking, to a portion of the hemisphere away from the sun.

A notable feature of the mission B orbit is the high altitude apoapsis of over 40,000 km. Initially apoapsis lies near the morning terminator and, as a result, the illuminated morning sector of Mars can be observed by the spacecraft for several hours on each revolution early in the mission. The afternoon sector is overflown as the spacecraft approaches periapsis so that, even at the beginning of the mission, the time spent above the afternoon side of Mars is less than an hour. As the mission progresses, Mars' heliocentric longitude increases at about 0.5 degree per day and apoapsis moves further onto the night side so that the planet-in-view period on each revolution is steadily reduced as shown in figure 2.

The nominal 4/3 harmonic period allows repeated observations of three regions, centered 120° longitude apart, with recurrent views every four Mars days. The observations are planned to investigate temporal variations of surface reflectivity with the particular objective of studying the 'wave of darkening' phenomenon. Minimal shadowing within the photographs is preferred and therefore the observations will be made with high solar elevation angles. "Variable features" photography of this kind will be acquired when the spacecraft is in the region of the noon meridian, at altitudes that vary from about 3500 km to about 2000 km throughout the mission (nominally 90 days in length).

Because apparent changes in surface reflectivity can be caused by variations in illumination and viewing geometry an effort has been made to minimize such changes. To compensate partially for illumination angle changes caused by the planet's varying heliocentric longitude the orbital period is increased slightly above the exact 4/3 harmonic. This period increase has the effect that the spacecraft crosses the local noon meridian at essentially the same Mars longitude on every third revolution throughout the mission. The northerly motion of the sub-solar point during the mission cannot be similarly allowed for. Because of the imprecise synchronization the spacecraft ground traces do not repeat exactly but instead are displaced westwards by about 2° longitude every four Mars days.

There are four principal types of photography planned for mission B and these will be described briefly in the order in which they will occur on a typical revolution. Certain limitations that are imposed on these sequences by the design of the nominal mission B orbit will also be mentioned.

1. Synoptic Meteorology Photography

During the relatively long planet-in-view periods early in the mission the spacecraft will acquire broad coverage photographs of the morning sector of Mars at roughly hourly intervals, beginning when the planet first comes into view and ending at about 2-3 hours before periapsis passage.

Intermixed with the synoptic photography will be photographs of regions of particular interest taken with a second camera (1.1° x 1.4° field of view) that provides an order of magnitude improvement in ground resolution. Such regions include particularly the Nix Olympica, Candor/Tharsis and Phoenicis Lacus zones because of the remarkable changes in brightness that they show on a diurnal cycle. It is considered that such changes may be indicative of water vapor exchange processes.[1] Ideally high resolution photography of these areas should be acquired at intervals for several hours. However, as will be discussed below, the longitudinal orientation of the mission B orbit relative to Mars may be unfavorable for viewing these regions for a long time on any revolution

2. 'High Sun' Variable Features Photography

Some aspects of the photography required for the study of seasonal surface reflectivity have already been outlined. On any revolution, when the spacecraft is near the local noon meridian, a mosaic of about a dozen wide angle frames will be acquired to provide coverage of a region about 60° longitude wide in a latitude band between about 10°S and 55°S. On three successive revolutions coverage is thereby acquired over a total of about 180° longitude. This coverage is repeated every four days and an investigation of the remaining longitudes would require that the longitudinal orientation of the orbit be changed at some point in the mission. Two propulsive maneuvers would be required: the first to 'unlock' and the second to resynchronize the period after the longitudinal orientation had migrated appropriately.

Because of the limited longitudinal coverage available to the 4/3 orbit consideration has been given to beginning the mission with an exploratory phase[2] lasting several revolutions before deciding upon the orbit's longitudinal orientation relative to Mars. Such a plan has been rejected because inadequate time is available to determine if temporal changes are taking place.

Presently the region considered most important for high sun observations is that centered at about 50°E which allows Sabaeus Sinus, Hellespontus, Hellas and Deucalionis Regio to be monitored. Orientation of the orbit so that it can observe this sector with the desired illumination conditions will require at least two trim maneuvers over a period of several days immediately following insertion. Two other sectors will automatically be observable to 'high sun' photography: those centered at 170°E and at 290°E. Such a longitudinal orientation of the mission B orbit, shown in figure 3, seems poorly suited for observations of the interesting regions of diurnal brightening mentioned above other than Candor/Tharsis.

In addition to providing data with which to look for temporal reflectivity changes the high sun photography will also be used to produce an albedo map of the regions covered. More complete longitudinal coverage is considered highly desirable and some such additional coverage may be provided by the photography taken on the revolutions that occur before the period is synchronized.

3. Limb Photography

Limb photography will be acquired on most revolutions using both the wide angle and the narrow angle cameras. Generally such photography will be acquired shortly before or after the high sun photography. The opportunity to observe the limb at all latitudes and longitudes, not possible with the 4/3 orbit, would be considered desirable.

4. Near-Periapsis Photography

The mission B orbit, with its lower periapsis altitude and more northerly periapsis location, can provide photography near the equator and in the northern hemisphere with twice the ground resolution available to mission A. For this reason some near-periapsis photography will be similar to that of mission A, namely, contiguous wide angle frames with interspersed narrow angle frames. The lower altitude of the mission B spacecraft necessitates off-vertical photography between successive frames to obtain overlap. Contiguity between adjacent swaths acquired four days apart is assured because the ground traces will be only 2° longitude apart.

Two other types of near-periapsis photography are also planned in which only the narrow angle camera is used: convergent stereo and contiguous high resolution coverage. The convergent stereo photography is theoretically capable of providing vertical resolution of the order of 100m. The success of this type of photography will be dependent upon the accuracy with which two narrow angle frames can be made to overlap when, as is the case, pointing uncertainties are significant relative to the frame size. Similarly, the amount of contiguous coverage obtainable between a number of narrow angle frames is not confidently known at present. There is little doubt, however, that interesting features will be observed on Mars that call for these types of photography.

Unfortunately the amount of terrain that will be accessible for near periapsis photography is very restricted because the spacecraft ground trace over each of the three sectors migrates only 45° during the 90 day mission. Thus near-periapsis photography can only be acquired over a total of only about 135° longitude. The orbit's likely orientation, indicated by figure 3, permits near-periapsis photography of the present prime Viking landing site[3] (Thoth Nepenthes, 15°N, 85°E) but does not permit such observations of the meteorologically interesting Phoenicis Lacus region (13°S, 252°E).

Proposed 5/6 Period for Mission B

From the above review it can be seen that each of the principal types of photography proposed for mission B is hampered to some extent by the limited longitudinal coverage available with the nominal 4/3 period. A large measure of relief from this constraint can be obtained if a different 'harmonic' is chosen for the mission B orbit. The choice of 5/6 rather than any other fraction is proposed on the following basis: a 5/6 period allows complete longitudinal coverage for the high sun photography with the shortest time between repeated observations and at the same time permits a complete tape load of recorded science data to be returned each revolution.

With a 5/6 period the spacecraft ground trace is displaced eastward by 60° every revolution (figure 4) in comparison to the 120° westward displacement of the 4/3 orbit. The 5/6 and 4/3 orbits are not significantly different, however, in the portion that lies within an hour on either side of periapsis as can be seen by comparing figure 5 with figure 1. The geometry of the high sun photography is therefore hardly changed. Repeated high sun coverage of each of six regions would be obtained at 5 day intervals compared with 4 days and only three regions for the 4/3 orbit. The 25% reduction in time resolution for the seasonal variations is amply compensated by the 100% increase in longitudinal coverage (from 180° to 360°) that becomes available for high sun photography.

Given complete longitudinal coverage for the investigation of seasonal albedo changes the longitudinal orientation of the orbit can, if desired, be trimmed to optimize the observation of regions that show diurnal brightening. There will, however, be an appreciable reduction in the planet-in-view period on each revolution early in the mission as shown in figure 2. This reduction leads to a loss of over one third in the time available for synoptic meteorology photography and therefore reduces the range of time-of-day during which regions can be observed. Opportunities for synoptic photography will, however, reoccur about every 21 hours instead of every 33 hours and a greater spread of longitudes will be observable. Moreover, certain regions will be observable on successive revolutions at different times of day thereby increasing the fraction of the diurnal cycle that can be followed for these regions.

The exact period proposed for the 5/6 orbit is 20.55 hours, the remaining orbital elements being unchanged. This period, like that of the 4/3 orbit, is slightly longer than the exact harmonic in order to allow for the planet's changing heliocentric longitude. The ground traces will, therefore, again migrate westward at about 0.5 degree per day so that near-periapsis photography will be possible over a spread of about 270° longitude during the nominal mission.

Given a 5/6 period and the consequently greater longitudinal coverage that would be available the importance of the lower mission B periapsis altitude would be significantly increased. Indeed mission B could be used to perform a mapping mission complementary to that of mission A by providing contiguous coverage over a large part of the northern hemisphere at double the mission A resolution. Such mapping could be important for planning of the 1976 Viking lander mission because at least one of the landers is likely to be targeted to the northern hemisphere.

Figure 6 shows the extent of the contiguous mapping possible from a 5/6 mission B over 90 days. The footprints that would be acquired in the middle of the mission have been omitted from the diagram. The assumption made in planning the near periapsis mapping is that about five frames would be available on each resolution with perhaps an equal number for narrow angle camera observations. Towards the end of the mission, when synoptic photography is no longer possible, it is assumed that a greater number of frames might be available and this is reflected in the figure.

An attractive feature of the 5/6 orbit is that it can be converted at any time to a wholly mapping function complementary to Mission A. This might be desirable in the second half of the mission if the continuation of the seasonal variations study becomes unattractive because of some photometric instability of the camera system.

Because a 5/6 orbit provides a good compromise between 'variable features' and 'fixed features' data return, the loss of one spacecraft might not be as critical an event as with the nominal Mission B design. Thus if the Mission A spacecraft failed after insertion of the Mission B spacecraft the latter could perform a reasonably satisfactory compromise mission, though coverage of the south polar region would be rather poor. If the failure of one spacecraft occurred before insertion of the surviving spacecraft then a 5/6 orbit with a $\sim 60°$ inclination would probably be desirable as a contingency orbit.

The adoption of a 5/6 orbit for Mission B would promise a certain simplification of the mission in that there would be no need to consider mid-mission propulsive maneuvers such as might be needed to change the regions of high sun photography or to acquire near-periapsis photography of some particularly exciting region. There would, however, still be a requirement to perform a period-reducing maneuver at the end of the nominal mission. At this time the spacecraft's orbit begins to take it into the shadow of Mars and a reduction in period lessens the time spent without solar power on any revolution, thereby increasing the chance that the spacecraft will survive this part of the mission. The same period-reducing maneuver is desirable for an additional reason, namely, to allow the spacecraft to closely intercept the orbit of the satellite Deimos and thereby significantly increase the spatial resolution of observations of this body. The required 'Deimos-interception' orbit period is about 15 hours[4] and it should be noted that a 5/6 Mission B orbit would provide better opportunities for Deimos photography than a 4/3 orbit because the ranges would be shorter and the opportunities more frequent.

One further advantage accrues to the 5/6 orbit: if one's ultimate objective is to enter a 15 hour period orbit, then an initial insertion into a 20.5 hour period orbit is more economical in terms of total $\Delta V$ required to reach the 15 hour orbit. A detailed calculation made by W. A. Webb at JPL indicates that about 30 m/s additional $\Delta V$ would be made available.[4]

Data Return from a 5/6 Orbit

The period of a 5/6 orbit is sufficiently long to assure the capability of acquiring and transmitting to earth a complete tape recorder load of data on each revolution. Tape recorder replay is prohibited during the 15 hours of each day that the elevation angle of Mars at the Goldstone receiving station is less than 15°. Since a complete recorder replay takes about three hours the proposed 20.55 hour orbital period would permit a minimum of 2.5 hours of data acquisition time on any revolution. Generally the complete planet-in-view period will be available for data acquisition but occasionally, on about one revolution in six, the required timing of the tape recorder replay will be such that it interferes with the acquisition of synoptic photography. The high sun and near-periapsis photography need not be affected. Since the orbital period proposed is less than 24 hours there will usually be only one tape replay during the 'Goldstone view period' but occasionally more than one replay will be required.

Summary

The proposed 5/6 Mission B orbit period (20.55 hours) provides a number of important advantages for the study of time varying phenomena and for mapping on account of the increased longitudinal coverage that it makes available. The data returned throughout the mission, at the rate of one tape load per revolution, is about 50% greater than that returned from a 4/3 (32.88 hours) orbit.

The principal disadvantage is the reduction, by about one third, in the planet-in-view period early in the mission.

1011-GAB-dmu G. A. Briggs

Attachment
References

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2. Briggs, G. A., "Mariner Mars '71 B Mission - A Candidate Exploratory Phase Mission Plan," Memorandum for File, March 30, 1970.

3. Young, A. T., "Minutes of Viking Project Landing Site Group Meeting No. 3," December 17, 1970.

4. W. A. Webb, "Deimos Intercept Characteristics for a MM'71 Mission B 20.548 Hr. Orbit," JPL Interoffice Memorandum, 392.4-318, January 12, 1971.

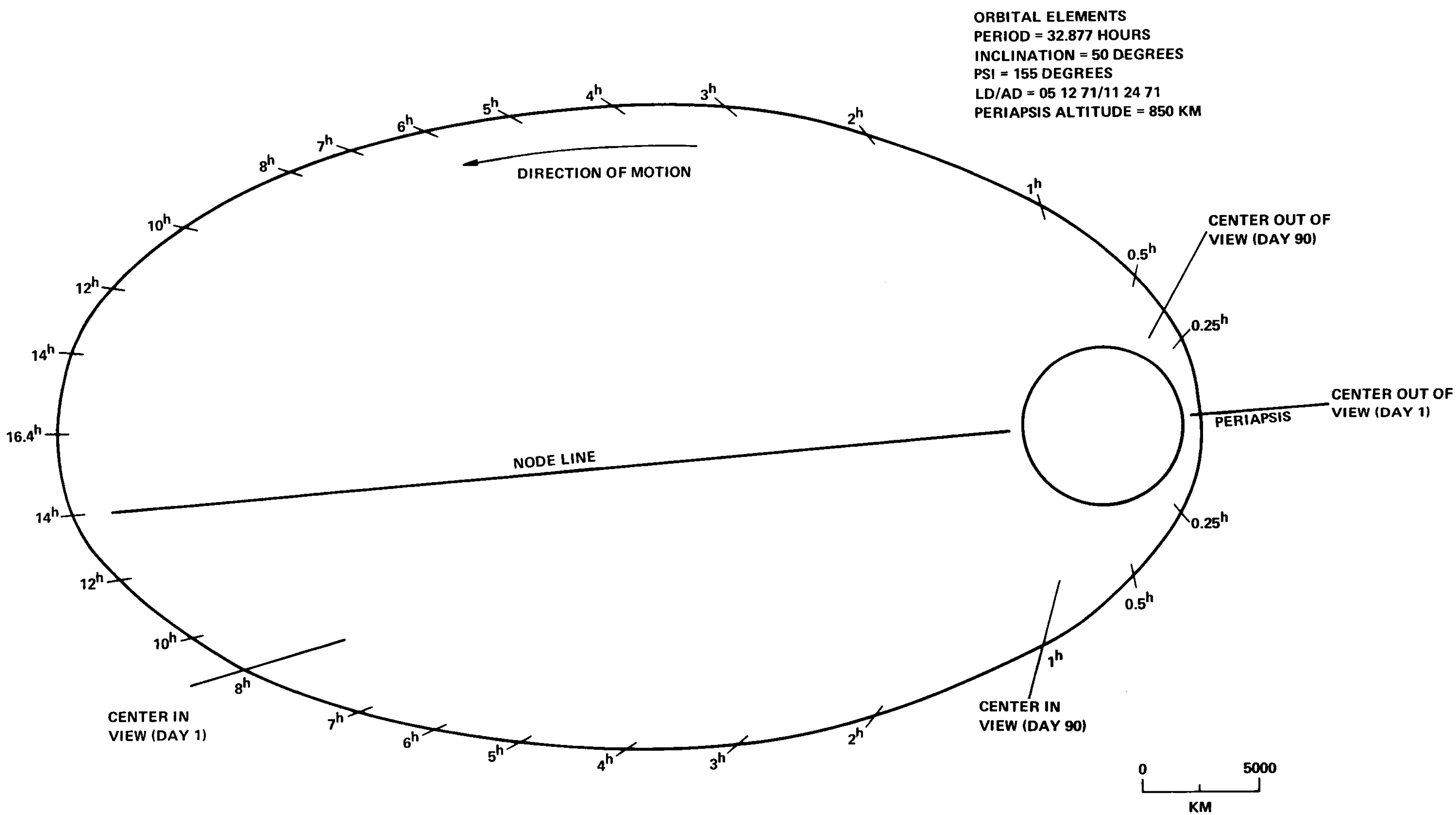


FIGURE 1 - VARIABLE FEATURES MISSION ORBIT WITH PERIOD OF 32.877 HOURS

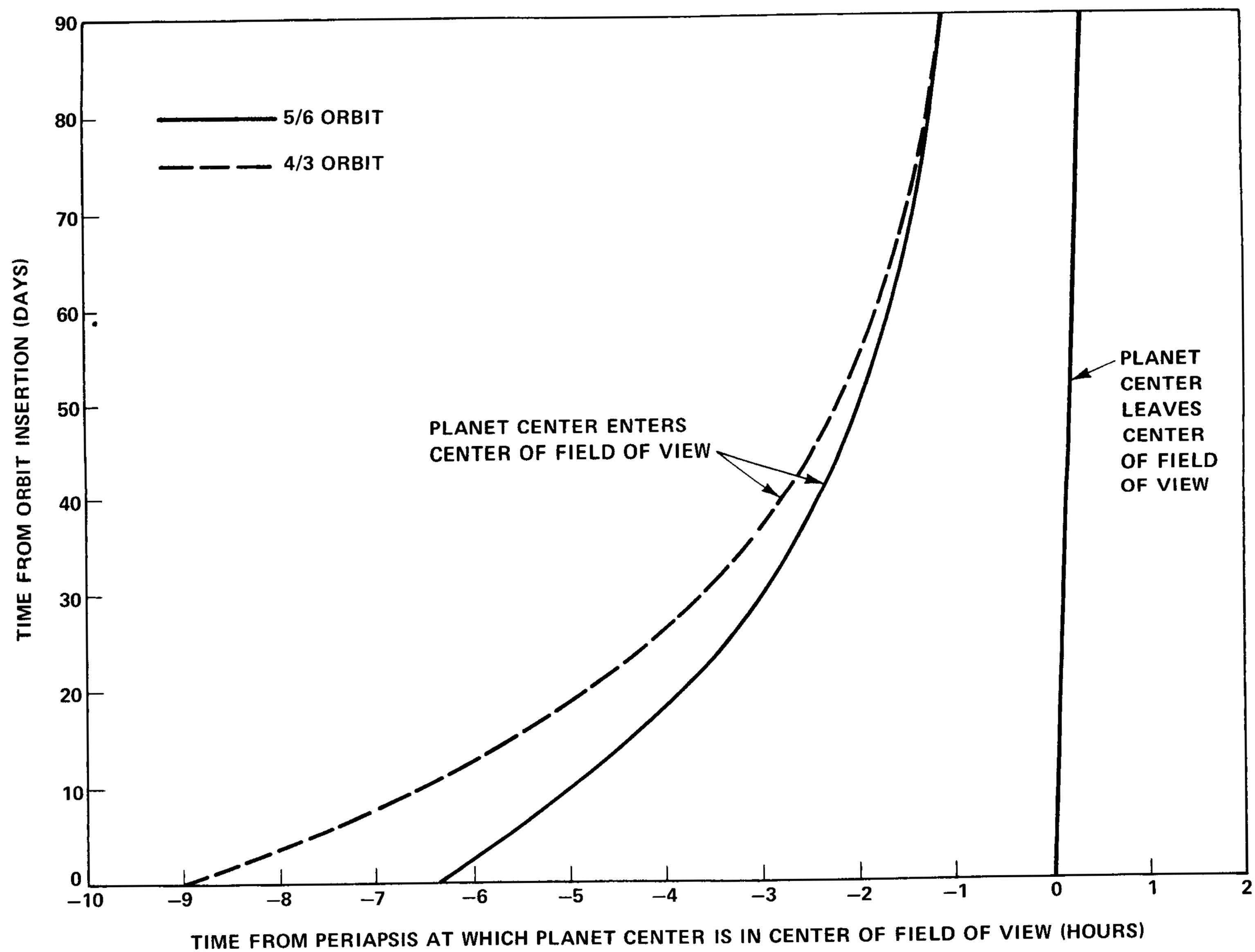


FIGURE 2 - VARIATION OF PLANET-IN-VIEW PERIOD AS A FUNCTION OF TIME FROM INSERTION FOR 5/6 AND 4/3 MISSION B ORBITS

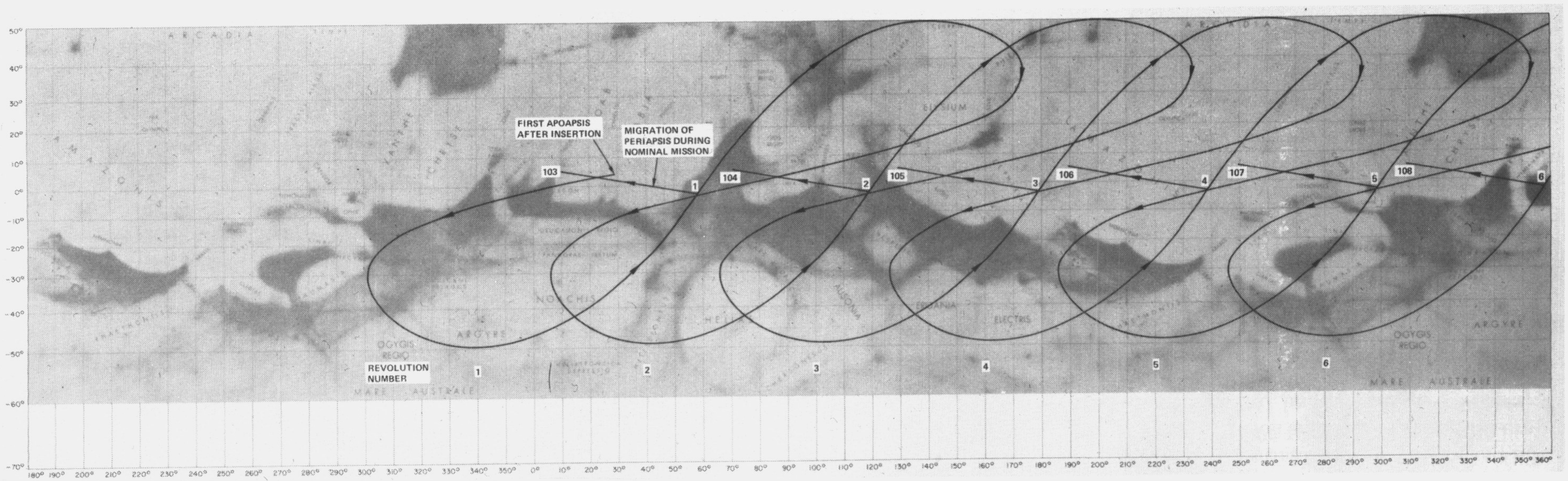


FIGURE 4 · SPACECRAFT GROUND TRACES FOR FIRST SIX REVOLUTIONS OF 20.548 HR. ORBIT. LONGITUDINAL LOCATION OF FIRST APOAPSIS IS ARBITRARY. MIGRATION OF PERIAPSIS AS FUNCTION OF REVOLUTION NUMBER IS ALSO SHOWN.

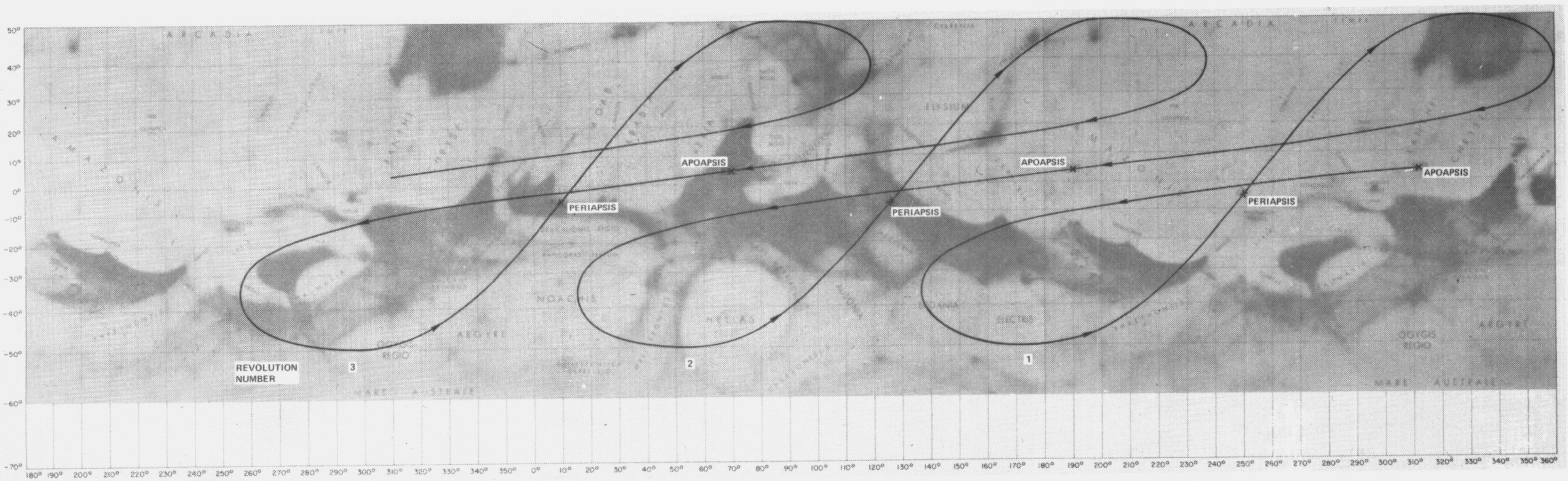


FIGURE 3 · SPACECRAFT GROUND TRACES FOR EARLY REVOLUTIONS OF 32.88 HOUR ORBIT. LONGITUDINAL ORIENTATION ASSUMED SUCH THAT SPACECRAFT CROSSES NOON MERIDIAN AT 50° E ON REVOLUTION 2

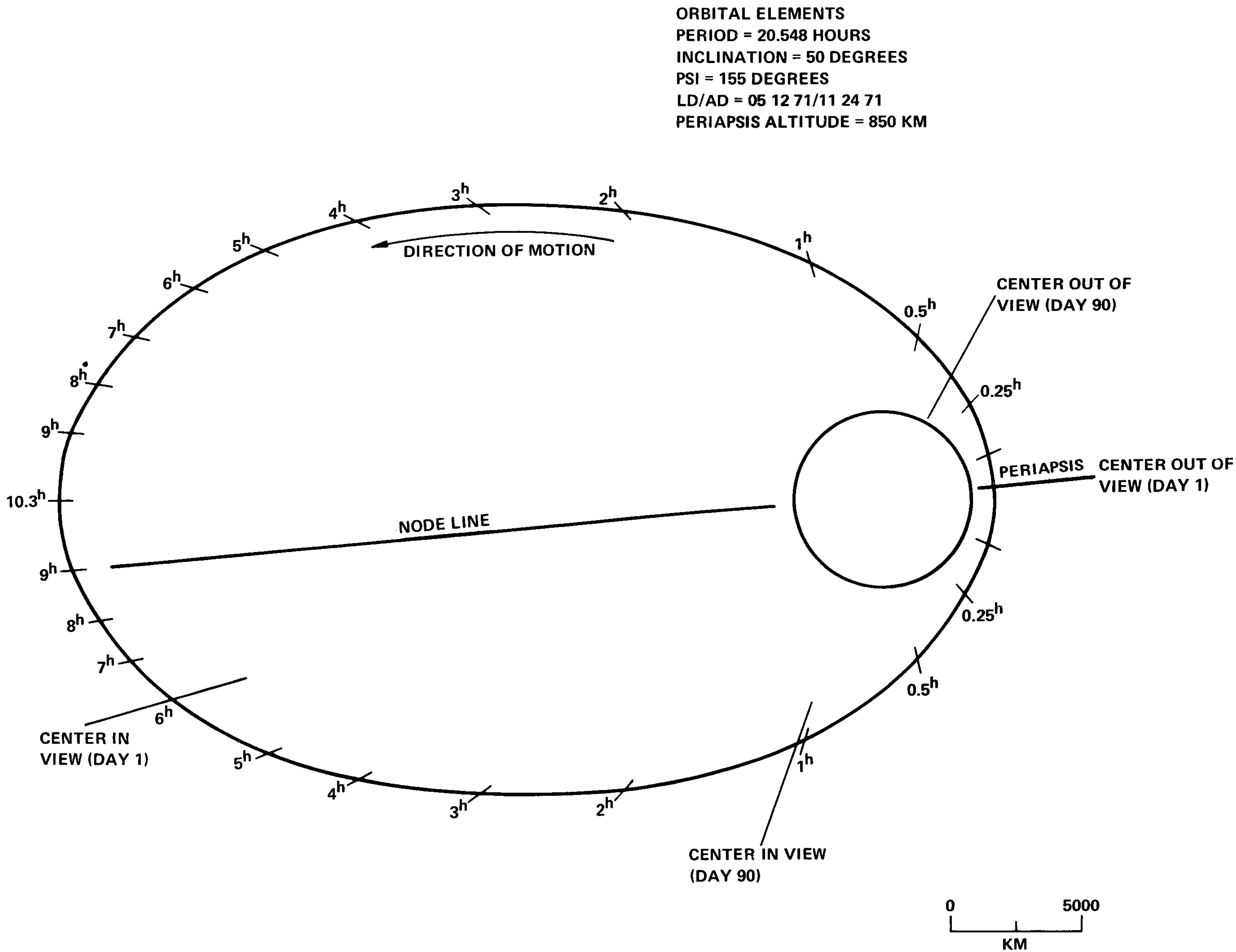


FIGURE 5 - VARIABLE FEATURES MISSION ORBIT WITH PERIOD OF 20.548 HOURS

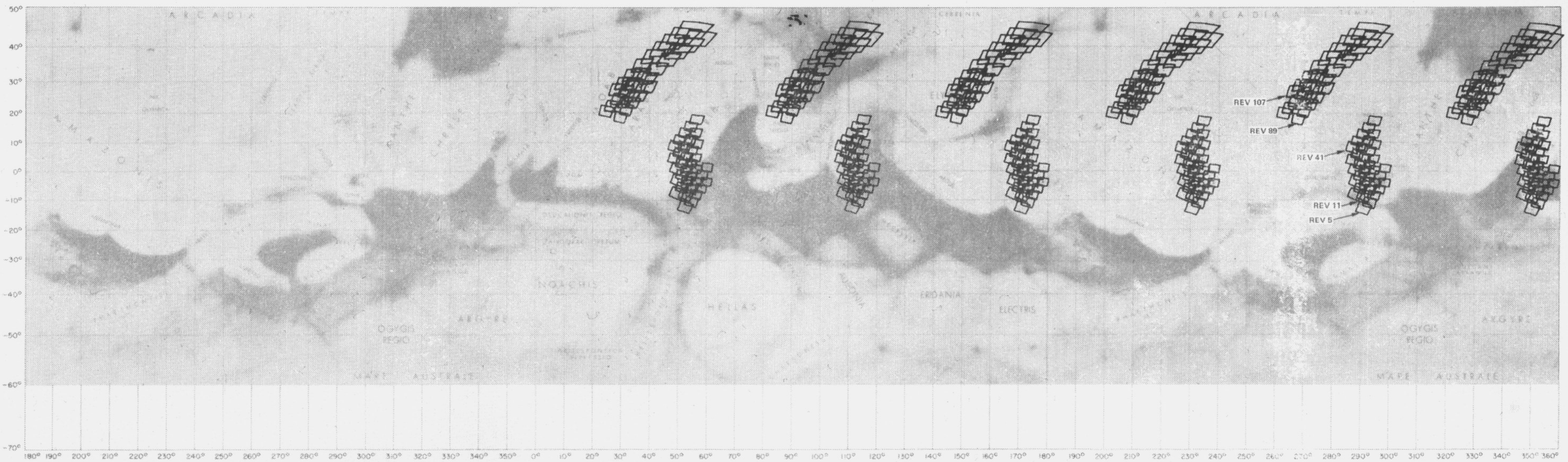


FIGURE 6 - CONTIGUOUS MAPPING COVERAGE ACQUIRED FOR 20.548 HR. ORBIT DURING NOMINAL MISSION. ASSUMES 5 A FRAMES PER REV ACQUIRED EARLY IN MISSION & UP TO 9 FRAMES PER REV TOWARDS END.

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